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Interest rate risk of life insurers – evidence from accounting data

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Non-technical summary

Research Question

Life insurers guarantee their customers fixed interest rates for a long period. However, the duration of their assets typically does not match the duration of their policies which exposes the life insurers to the risk of falling interest rates. Quantitatively, little is known about interest rate risk because these companies do not report it in their financial statements. In recent years, however, interest rate risk taken on in the past has partly materialized. Against this background, this paper examines the interest rate risk of life insurers.

Contribution

An important indicator for measuring interest rate risk of insurers is the duration gap, which is the difference in interest rate sensitivity between assets and liabilities. The wider the gap, the greater the risks when interest rates fall, because the value of liabilities grows more strongly than the value of assets. I show how to estimate the duration gap with data from external accounting. The calculation is based on differences between the book and market values. The indicator is calculated for German life insurers. This offers an insight into the distribution and determinants of interest rate risk. This is important for assessing the contribution of the insurance sector to risks to financial stability.

Results

The calculation at the insurer level yields on average a wide duration gap for German life insurers with pronounced heterogeneity in the cross-section. This indicates that insurers are exposed to quite different degrees of interest rate risk. A wide dispersion implies differences in terms of the management of interest rate risk. Therefore, insurers are likely to respond differently in their investment decisions to falling interest rates. This reduces the degree of alignment in their behavior and, thereby, potential risks to financial stability.

Nichttechnische Zusammenfassung

Fragestellung

Ihren Kunden garantieren Lebensversicherer für eine lange Laufzeit eine Mindestverzinsung. Hierbei ist jedoch die Laufzeit ihrer Kapitalanlagen typischerweise geringer als die Laufzeit der Versicherungsverträge. Dies setzt Lebensversicherer einem Risiko gegenüber fallenden Zinsen aus. Es ist quantitativ wenig über dieses Zinsänderungsrisiko bekannt, denn diese Unternehmen müssen hierzu in ihren Geschäftsberichten nichts veröffentlichen. In den letzten Jahren hat sich das in der Vergangenheit eingegangene Zinsänderungsrisiko teilweise materialisiert. Vor diesem Hintergrund wird die Höhe des Zinsänderungsrisikos von Lebensversicherern untersucht.

Beitrag

Eine wichtige Kennzahl zur Messung des Zinsänderungsrisikos von Versicherern ist die Durationslücke, der Unterschied in der Zinssensitivität zwischen Vermögensgegenständen und Verbindlichkeiten. Je höher die Durationslücke, desto größer sind die Risiken aus fallenden Zinsen. Denn in diesem Fall steigt der Barwert der Verbindlichkeiten stärker an als der Barwert der Vermögensgegenstände. Es wird gezeigt, wie man mit Daten aus dem externen Rechnungswesen die Durationslücke abschätzen kann, wobei die Berechnung auf Unterschieden zwischen Buch- und Marktwerten beruht. Diese Kennzahl wird für die deutschen Lebensversicherer berechnet. Dies ermöglicht einen Einblick in die Verteilung und die Einflussfaktoren von deren Zinsänderungsrisiken, was bedeutend für die Bewertung des Beitrags des Versicherungssektors zu Risiken für die Finanzstabilität ist.

Ergebnisse

Die Berechnung auf Einzelinstitutsebene ergibt im Mittel für deutsche Lebensversicherer eine hohe Durationslücke, wobei die Werte im Querschnitt breit gestreut sind. Dies deutet darauf hin, dass deutsche Versicherer in unterschiedlichem Maße Zinsänderungsrisiken ausgesetzt sind. Eine große Bandbreite impliziert Unterschiede im Hinblick auf das Management dieser Risiken. Daher dürften die Versicherer auch bei ihren Kapitalanlageentscheidungen unterschiedlich auf fallende Zinsen reagieren, was die Gefahr gleichgerichteten Verhaltens und damit mögliche Risiken für die Finanzstabilität reduziert.

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Interest Rate Risk of Life Insurers - Evidence from Accounting Data *

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Abstract

Life insurers are exposed to interest rate risk, and their liability side is typically more sensitive to interest rate changes than their asset side. This paper develops an accounting-based measure of interest rate sensitivity. My approach uses the coexistence of historical cost and market value accounting, which permits the observation of valuations for different discount rates. Using microdata, I show that German life insurers have a significant exposure to interest rate risk. However, there is a wide dispersion across the sector. I find that insurers' size, growth and solvency are negatively correlated with interest rate risk. The heterogeneity suggests that insurers would behave differently during times of stress, which has important implications for understanding the macroprudential risks to which the sector is exposed.

Keywords: Life insurance, interest rate risk, asset liability management, duration gap

JEL classification: E43, G11, G22

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1 Introduction

Endowment and annuity life policies often promise to pay fixed interest payments on long-term contracts. Insurers have to deliver on their promises irrespective of their interest income from investments. To reduce interest rate risk, life insurers seek to match the maturities of their interest-bearing assets and liabilities. However, asset-liability matching is often imperfect, and insurers engage in maturity transformation. The liabilities of life insurers, unlike those of banks, typically have maturity profiles that are longer and thus more sensitive to interest rate changes than those of investments. Life insurers therefore tend to benefit from rises in interest rates but lose if interest rates fall.

Solvency II, the new European insurance regulation regime, measures interest rate risk based on a stress test approach as the decrease of asset over liability value given a shift in the yield curve. Hence, the duration gap - the difference in interest rate sensitivity between liabilities and assets - is a key indicator within the Solvency II framework. It is also a key factor in the optimization of investment portfolios with regard to expected return and capital requirements (Braun et al. 2017). If a wide duration gap constrains insurers' capital, it will incentivize them to take on more investment risk ((Becker and Ivashina, 2015)). In the long run, a wide gap gives rise to reinvestment risk. Future interest income is uncertain and, as a consequence of falling interest rates, future interest income may fall short of interest expenses (French et al. 2015). As IMF (2016) highlights, the duration gap also contributes to macroprudential risk, because it increases the common exposure within the insurance sector. The idea is that if life insurers suffer similarly from falling interest rates, they may, in times of stress, be inclined to adapt their investment portfolios in a similar fashion. This could exacerbate the repercussions of insurers' behavior for other markets and contribute to systemic risk.

In the literature so far, there are two ways to estimate the interest rate risk of insurers. *First*, in a purely bottom-up approach, the European insurance regulator EIOPA (2014) and (2016) estimates, in the context of its stress tests, the interest rate risk at the country level. It uses detailed internal cash flow data requested from a sample of insurers for this purpose. GDV (2015) uses a similar approach, but this study is unpublished. A bottom-up approach is convenient, though owing to data contraints it is not feasible for most research purposes. Furthermore, there is a lack of replicability and transparency because researchers cannot observe the calibrations and assumptions of insurers' internal models. *Second*, Brewer et al. (2007), Berends et al. (2013) and Hartley et al. (2016) use a top-down approach estimating the interest rate sensitivity of insurers' stock prices. However, the main constraint here is that only a few insurers are listed, and those that are, typically operate several business segments other than life insurance.

This paper develops a new accounting-based estimate of interest rate risk at an insurer level. My top-down approach is based on a comparison of fair value accounting and historical cost accounting data. The basic idea is to use two valuations that only differ in the underlying discount rates. To estimate sensitivity, I relate the difference between the two valuations to the change in the discount rate. The difference in the sensitivity of assets and liabilities is an estimate of an insurer's (modified) duration gap. The estimate is historical because my accounting-based approach is backward-looking, which means I estimate interest rate sensitivity at the time of recognition on the balance sheet. To my knowledge, this is the first study which estimates insurers' interest rate risk using accounting data. My approach permits a study of interest rate risk for the entire life insurance sector within a jurisdiction and an estimation of the risk distribution. This has important implications for macroprudential risk, because the heterogeneity of interest rate risk might affect the alignment in behavior, which could have repercussions for other markets. Furthermore, my estimate permits a study of the cross-sectional association between Solvency II coverage ratios and interest rate risk. One would expect a positive correlation because the duration gap is an important determinant of Solvency II capital requirements.

As an application, I calculate the interest rate sensitivity of German life insurers. For this purpose, the analysis exploits data from a recently enacted law, which makes it possible to approximate the market value of German life insurers' liabilities. In other respects, German accounting rules for life insurance entities are based on a form of historical cost accounting. This permits me to observe two valuations with different underlying discount rates. German life insurers offer mainly endowment policies, which pay a lump sum either after a predefined time horizon or in case of the death of the policyholder, and annuity policies. Both policies are long-term contracts with guaranteed minimum returns for the entire term. Therefore, the case of German life insurers is particularly interesting because of its typical market characteristics which make liabilities highly sensitive to interest rates. In line with this assessment, the EIOPA (2014) estimate for the duration gap of Germany's life insurance sector is eleven years, which is one of the widest of all the countries included in its analysis. By contrast, life insurers in countries such as the United States and the United Kingdom usually have only a narrow duration gap or none at all. The wide duration gap of German life insurers attracts widespread interest, including from the IMF (2015). Recent studies such as Kablau and Weiß (2014) and Berdin and Gründl (2015) illustrate that German life insurers are particularly vulnerable to low interest rates.

In line with the high interest rate risk of German life insurers, I obtain a median modified duration gap for German life insurers of 6.1. This means that, for the median insurer, a one percentage point drop in interest rates leads to an increase in the market value of liabilities that is approximately six percentage points greater than the relative increase in the market value of assets. I observe that most insurers have a significant duration gap, though the magnitude differs widely between insurers. I also investigate the extent to which insurer attributes can explain differences in interest rate risk. Higher interest rate risk is associated with lower Solvency II ratios. Further regression results indicate that an insurer's size and growth are negatively correlated with interest rate risk.

The remainder of the paper is organized as follows. Section 2 elaborates on how different accounting valuations can be used to calculate a measure of interest rate risk. Section 3 presents the data, and explains the institutional context and the relevant accounting rules and calibrations that characterize the situation in which German life insurers operate. Section 4 calculates the historical duration gap using company-level data. It also analyzes the distribution and the relationship to insurer attributes. Section 5 concludes the paper.

2 Interest rate sensitivity estimate using accounting data

Modified duration (Dur) is a measure of interest rate sensitivity. Assuming a flat yield curve, it is defined as a semi-elasticity, the relative change in the market value MV for an absolute change in the interest rate r:

$$Dur \equiv -\frac{\partial MV}{\partial r}\frac{1}{MV} \tag{1}$$

Consider MV as the market value of an insurer's assets or its liabilities. Generally, the market value increases as interest rates fall ($\partial MV/\partial r < 0$). I consider the development between two interest rate levels r_0 and $r_0 + \Delta r$. I relate the change between two market values for the two interest rate levels MV_{r_0} and $MV_{r_0+\Delta r}$ to a change in interest rates from r_0 to $r_0 + \Delta r$. This approximates the interest rate sensitivity as a linear function. The comparison of two market values with different underlying interest rates implies the assumption that changes observed in the market value are predominantly attributable to a change in the level of interest rates. This is valid because life insurers predominantly invest in fixed-income securities, and liabilities are calculated as the present value of guaranteed future payments. A further assumption is that portfolios do not change when r_0 and $r_0 + \Delta r$ are observed. At point r_0, which is the level before the interest rate changes, the modified duration Dur_{r0} is approximately the following:

$$Dur_{r0} \approxeq -\frac{MV_{r0+\Delta r} - MV_{r0}}{MV_{r0}}\frac{1}{\Delta r} \tag{2}$$

I now consider a historical cost accounting regime. Each item has two observable valuations: the book value at historical cost BV and the market value MV. I only observe $MV_{r0+\Delta r}$ and $BV_{r0+\Delta r}$, but I do not observe MV_{r0} and BV_{r0}. I approximate MV_{r0} with a book value $BV_{r0+\Delta r}$, which is sensible if two conditions are met. First, the book value and market value were identical when rates are r_0. And second, the book value does not change when rates change ($BV_{r0+\Delta r} = BV_{r0} \forall \Delta r$) .

These conditions are typically met in a strict historical cost accounting regime. I transform Equation (2) with a view to deriving an equation that can be calculated with the available information. I set r_0 such that assets and liabilities were recognized on the balance sheet at this interest rate level. Therefore, at interest rate level r_0, the book value equals the market value. That way, the modified duration can be approximated by the standardized amount by which the market value differs from the book value relative to the underlying change in interest rates.

$$Dur_{r0} \approxeq -\frac{MV_{r0+\Delta r} - BV_{r0}}{BV_{r0}}\frac{1}{\Delta r} \tag{3}$$

Equation (3) only considers the value effect of a change in interest rates. I now consider that, after the interest rate change, some time passes until the current year, the observation time. Given a finite time to maturity any present value is sensitive to the passing of time. The sensitivity to the passing of time increases in the discount rate.[1] I set the current year as $v_0 + \Delta v$ and the time of interest rate change in the past as v_0 with $\Delta v > 0$. Δv represents the number of years that have passed. The following holds:

$$Dur_{r0,v0} \approxeq -\frac{MV_{r0+\Delta r,v0} - BV_{r0,v0}}{BV_{r0,v0}}\frac{1}{\Delta r} \tag{4}$$

Equation (4) is the similar to Equation (3), apart from the stipulation that the interest rate change takes place without any time passing. My goal is to approximate the change in book and market values for a change in observation time. For a simple presentation I use a valuation at different years z of a zero-coupon bond with face value a and time to maturity T. The market value is discounted using the current interest rate $r_0 + \Delta r$. The book value is still discounted using the pre-change interest rate r_0 because it is not sensitive to interest rate changes. Note that is necessary to also consider the time passing effect of the book value even in a historical cost accounting regime. In such a regime,

[1] Cf. Chance and Jordan (1996) for background on the effect of time on the price of financial securities.

the book value changes when the time value changes because of a later observation time. Book and market values conditional on observation year $z \in \mathbb{N}$ can be written as:

$$MV_{r_0+\Delta r}(z) = \frac{a}{(1+r_0+\Delta r)^{T-z}} \tag{5a}$$

$$BV_{r_0}(z) = \frac{a}{(1+r_0)^{T-z}} \tag{5b}$$

This means that the face value is discounted back to an earlier date with a later year z. The sensitivity of to a change in z is the following:

$$\frac{\partial MV_{r_0+\Delta r}}{\partial z}\frac{1}{MV_{r_0+\Delta r}} = \frac{ln(1+r_0+\Delta r)a}{(1+r_0+\Delta r)^{T-z}}\frac{1}{MV_{r_0+\Delta r}} = ln(1+r_0+\Delta r) \tag{6a}$$

$$\frac{\partial BV_{r_0}}{\partial z}\frac{1}{BV_{r_0}} = \frac{ln(1+r_0)a}{(1+r_0)^{T-z}}\frac{1}{BV_{r_0}} = ln(1+r_0) \tag{6b}$$

In the following, I consider the value change for an absolute time change. The use of a long-term zero-coupon bond in Equations (5a) and (5b) is a simplification because it does not require an assumption about reinvestments. A payment structure with earlier payments, for example a coupon bond, would reduce the approximate change in value with a small change of z. The exact time structure of payments is not known. To account for the share of net cash flows with a present value that is insensitive to the passing of time, I consider in the following only half of the marginal increase. Based on this, I approximate the value change for a time change of Δv years. The time structure is that interest rates changed from r_0 to $r_0 + \Delta r$ just after the item was recognized on the balance sheet and then, from time v_0, a time Δv passed while interest rates remained constant. This gives the following approximate relationship between the value at interest level $r_0 + \Delta r$ for different times.

$$MV_{r_0+\Delta r, v_0+\Delta v} \approxeq (1+ln(1+r_0+\Delta r))^{0.5\Delta v}\, MV_{r_0+\Delta r, v_0} \tag{7a}$$

$$BV_{r_0, v_0+\Delta v} \approxeq (1+ln(1+r_0))^{0.5\Delta v}\, BV_{r_0, v_0} \tag{7b}$$

Then, I derive the following estimate of the book market difference which considers the time passing effect:

$$MV_{r_0+\Delta r, v_0} - BV_{r_0, v_0} \approxeq \frac{MV_{r_0+\Delta r, v_0+\Delta v}}{(1+ln(1+r_0+\Delta r))^{0.5\Delta v}} - \frac{BV_{r_0, v_0+\Delta v}}{(1+ln(1+r_0))^{0.5\Delta v}} \tag{8}$$

This gives the following approximation of the duration prior to the change in interest rate level and time:

$$Dur_{r_0,v_0} \approxeq - \frac{\frac{MV_{r_0+\Delta r, v_0+\Delta v}}{(1+ln(1+r_0+\Delta r))^{0.5\Delta v}} - \frac{BV_{r_0,v_0+\Delta v}}{(1+ln(1+r_0))^{0.5\Delta v}}}{\frac{BV_{r_0,v_0+\Delta v}}{(1+ln(1+r_0))^{0.5\Delta v}}} \frac{1}{\Delta r} \tag{9}$$

The duration estimate is therefore the relative change in the valuation of market over book value divided by the interest rate change, where the book and market values are the currently observed valuations discounted back to the time of recognition on the balance sheet. Because the book value is discounted at another rate than the market value, the difference in valuation between the market and book values changes through discounting relative to the undiscounted difference. This reflects that the currently observed difference in valuation differs from the original valuation difference.

Using Equation (9) one can, in principle, separately calculate the duration of liabilities $Dur^{Liabilities}_{r_0,v_0}$ and the duration of assets $Dur^{Assets}_{r_0,v_0}$. The historical duration gap is defined as the difference between the two.

$$Durationgap = Dur^{Liabilities}_{r_0,v_0} - Dur^{Assets}_{r_0,v_0} \tag{10}$$

This difference should be interpreted as a comparison of sensitivities, and not as a difference in value changes, because the asset value usually exceeds the liability value. However, if the asset value and the liability value do not differ much (as it normally the case) the duration gap is a good approximation of the net value change, standardized by the asset value.

3 Application to German life insurers

3.1 Data set

I analyze the interest rate risk of German life insurers using the extended forecast for 2014 collected by the Federal Financial Supervisory Authority (*BaFin*). The publicly unavailable cross-sectional data set includes detailed reports from the financial reporting systems of all German life insurers. The data are based on company business plans as at 30 September 2014 for full-year 2014, assuming stable capital market conditions for the fourth quarter of 2014. The detailed accounting and business plan data are collected in the process of preparing financial statements but do not end up being published.

I use the premium reserve (*Deckungsrückstellung*) as the insurers' liability. Life insurers create this provision to provide for future net benefit obligations that have already been entered into and are attributable to individual policies. With regard to the premium reserve, the data set shows the hidden losses, which are the difference between a market value estimate and the book value. The data set also includes information on the book value of investments as well as on the valuation reserves, which are the difference between market and book values. Regarding the premium reserve, the data set also reports the insurer-specific average discount rate for the book value and an industry-wide discount rate for the market value. As for insurers' investments, both discount rates need to be estimated. I estimate the discount rate for the book value at an insurer level based on average yearly coupon payments. Regarding the discount rate for the market value, I use an aggregate estimate based on the average current yield of debt securities in Germany.[2]

My approach concentrates on the interest rate sensitivity of guaranteed benefits and disregards future discretionary benefits. To this end, this paper focuses on the local GAAP accounting item which considers only fixed future payments. Since future discretionary payments cannot be reduced below zero, this constitutes the interest rate risk related to the lower bound of future outpayments. Because the analysis is based on local GAAP accounting data, this paper does not approximate the interest rate sensitivity of own funds in a Solvency II context.[3]

The data contain 86 life insurers, of which I exclude three insurers with missing observations. These three are very small insurers - all three combined have a premium reserve of around 0.25 billion euro compared to an average premium reserve of 9 billion euro. This leaves me with a sample of 83 German life insurers.

On aggregate, the key figures are as follows. I observe that the premium reserve has a book value of 750 billion euro. The average underlying discount rate is 3.1%. The observed market value of the premium reserve is 923 billion euro, with an underlying discount rate of 1.2%. This means that the market value of the premium reserve is 173 billion euro, or 23% higher than the historical cost accounting value. This difference in value corresponds to an average decrease in interest rates by 1.9 percentage points. The book value of investments is 818 billion euro. The average underlying discount rate is 3.7%. The market value of investments is 954 billion euro, with an average discount rate of 0.8%. This means that the market value of investments is 136 billion euro, or 17%

[2] Yields on debt securities outstanding issued by German residents, Bundesbank time series BBK01.WU0017.

[3] EIOPA (2014) examines Solvency II technical provisions and assumes a fixed best estimate cash flow. However, some cash flows used for calculating the technical provisions actually move when interest rates decrease. The approach does not consider to split guaranteed benefits and future discretionary benefits. The latter depend on insurers' future profits and, therefore, have a risk-mitigating effect (Wagner and Lazic, 2016). An alternative approach to estimating the duration of liabilities is to use scenarios: first, the present values of future cash flows are calculated for the baseline and a stress scenario. This calculation can be based on an assumption as to how future discretionary benefits respond to market interest rates. Then, the change in the present value is expressed in relation to the change in interest rates. EIOPA (2016) considers as an alternative measure an approach of this kind called effective duration. It yields a lower interest rate sensitivity estimate than an approach that uses a fixed best estimate cash flow. However, the result can only be interpreted with respect to the scenarios compared. In particular, EIOPA's stress scenario assumes a flattening of the yield curve.

higher than the historical cost accounting value. This difference in valuation corresponds to an average decrease in interest rates by 2.9 percentage points. Already, this comparison suggests that liabilities are more sensitive to interest rate changes than assets.

3.2 Basics of German insurance accounting

German life insurers prepare their single-entity financial statements in accordance with the German Commercial Code (*HGB*) and regulatory provisions. In the following I explain the German national GAAP used in insurance accounting in greater detail.

On the asset side, investments are, in principle, valued at at the higher of current market value or historical cost. In the low-interest-rate environment, this implies that most investments - the vast majority of which are fixed-income securities - are carried at par value. Insurers also report their valuation reserves, which are the difference between market and book values. For this reason, I effectively observe two valuations of investments that differ mainly due to the discount rate used.

As for the liability side, I focus on the premium reserve (guaranteed benefits). The premium reserve is generally valued as the present value of expected cash flows. It consists of two parts, an interest-rate-insensitive reserve (denoted here as the book value) and an interest-rate-sensitive surcharge, the additional interest provision (*Zinszusatzreserve*). The interest-rate-insensitive reserve is discounted at a rate determined by the contract inception year. This rate applies to the entire term of the policy and is typically identical to the guaranteed rate of the respective insurance policy. The surcharge uses the rolling average of rates over a ten-year period as the discount rate. It only covers obligations for the next 15 years, so there is no interest-linked surcharge for years 16 and thereafter. The surcharge has the effect, in principle, of adjusting the level of reserves towards the market value. The reasoning is to increase provisions for underprovisioned policies. However, the adjustment is only partial, and there remains a significant portion of hidden losses.

It recently became possible to observe the market value of insurer liabilities. In 2014 there was a major reform in Germany, the Life Insurance Reform Act, which included a block on dividend payouts. Insurers are only allowed to distribute dividends depending on the hidden losses carried on the liability side. The hidden losses of the premium reserve are approximated by the safeguard amount (*Sicherungsbedarf*). This is the difference between the present value using the current market interest rate as the discount rate and the sum of the book value and the additional interest provision. Therefore, I effectively have two valuations of the premium reserve which differ only in terms of their discount rate. The difference between the two valuations, the book value and the market value, is the sum of the safeguard amount and the additional interest provision.

The time passing effect regarding investments and the book value of the premium reserve can be approximated as outlined above. However, the time passing effect of the market value of the premium reserve cannot be estimated with the general approach outlined above because of measurement specifics: the safeguard amount each year covers exactly the next 15 years. If the observation year were to move forward, the time period of 15 years would remain constant, but the years included would change. For example, if one measures the hidden losses in year $n + 1$ rather than in year n, one then observes hidden losses from year $n + 1$ until $n + 15$, rather than from year n to $n + 14$. Therefore, the hidden losses measure keeps itself up to date. For this reason, in the specific case of German insurance accounting, one needs not account for the time passing effect of the difference between market and book value.

3.3 Estimate of time passed since recognition on the balance sheet

To calculate the sensitivity of investment valuation to time passing, one estimates Δv , which is the time period between today and the point of time when the average investment was purchased or the average contract was concluded.

For the liability side, I estimate Δv at an insurer level by using the policy structure set out in the yearly industry report from the rating agency Assekurata. This includes a contract breakdown by guaranteed interest rate for 64 life insurers (89% market share). This breakdown can be used to derive a contract breakdown by starting year because each observed guarantee rate was only valid for a few years. This approach gives me an average contract age estimate of 13 years with a standard deviation of 2.4.

For the investment side, I base my estimate on the current return on investments, which only includes regular payments such as coupon payments but excludes valuation effects. A bond's yearly coupon payment is a good proxy of that bond's yield at the time it was issued. The underlying assumption is that, at the time of buying a bond, the yield does not systematically differ from the yearly coupon payment. I match, at an insurer level, the current return on investment and the investment yield on a typical investment by year in the past. For this purpose, I use yields on German mortgage covered bonds outstanding with ten years' maturity.[4] This results in an average asset age of 6.0 years with a standard deviation of 0.5.

[4]Bundesbank time series BBK01.WX4260. Mostly, interest rates decreased over time. If they did not for a certain year, I would interpolate.

4 Results

4.1 Estimation of the historical duration gap

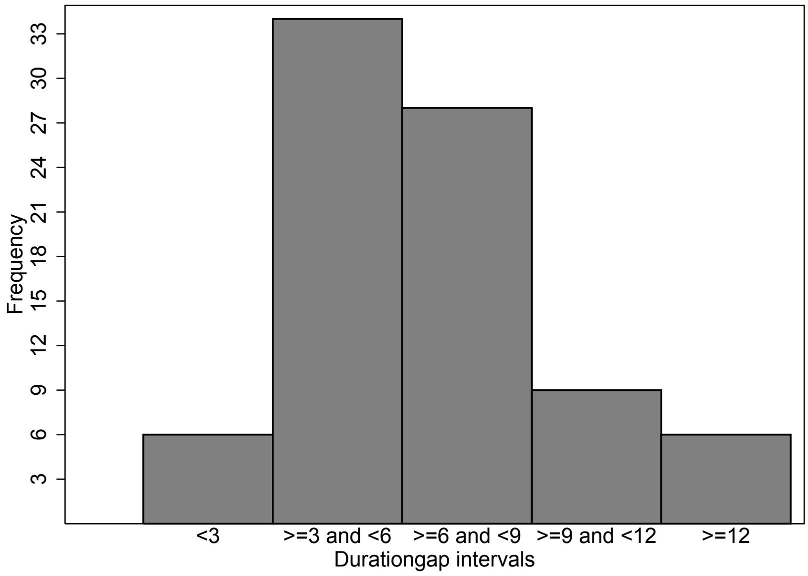
In aggregate, the historical modified duration gap of life insurers amounts to 4.9. This means that a one percentage point decrease in interest rates leads to an increase in the market value of liabilities that is approximately five percentage points greater than the relative increase in the market value of assets. This is the result of an investment duration of 9.9 and a liability duration of 14.7. The aggregate view weighs larger insurers more heavily than smaller ones. The median modified duration gap is 6.1. The unweighted average duration gap is 6.8 with a standard deviation of 3.9. The median duration gap of the ten largest insurers is only 4.4. All this implies that smaller insurers tend to have a wider duration gap.

By comparison, EIOPA (2014) estimates the current (Macaulay) duration for assets at 10 and for liabilities at 21. Assekurata (2015) estimates the modified duration for fixed-income investments at 8 for 2011, with an upward trend since that time. They do not publish an estimate of the duration for liabilities. GDV (2015) estimates the modified duration for fixed-income investments at 7 for 2009, again with an upward trend since then, and the duration for liabilities at 15 (no estimate for different years). Domanski et al. (2015) estimate the asset duration at about 10 for 2010 with an upward trend since. Note that I cannot observe all the hidden losses at the long end and therefore potentially underestimate the liability duration. The actual duration gap might therefore be wider.

The broad distribution shown in Figure 1 reveals a wide dispersion between insurers. The wider the dispersion of interest rate risk, the less likely it is that insurers will respond in a similar fashion to interest rate changes and the less likely it is that their behavior could have repercussions for other markets. The insurers with particularly large duration gaps tend to be small.

Table 1 displays sensitivities of the aggregate duration estimate. The estimate is indeed sensitive to variations in parameters, though the result of a significant duration gap does not change. For example, if one considered a decrease of Δr, the difference in the discount rate of the book and market value of assets, of 3.0% instead of 2.9%, the estimated aggregate investment duration would decrease by 0.2 to 9.7, and the duration gap would increase by 0.2 to 6.3. If one ignored the time passing effect, the aggregate duration gap estimate would increase from 4.9 to 6.3, with an asset duration of 5.8 and a liability duration of 12.1.

Figure 1: Histogram of the estimated historical modified duration gap of German life insurers



The histogram shows the distribution of the historical modified duration gap estimated in Equation (10) for 83 German life insurers. Each bin illustrates the number of insurers with a duration gap within the interval. The duration gap is derived from a comparison of historical cost and fair value accounting data and from the average change in underlying interest rates. The wider the historical duration gap, the more an insurer is exposed to interest rate risk at the time the average asset and liability was recognized on the balance sheet.

Table 1: Sensitivities of duration estimates

		Column (1)	Column (2)
		Aggregate duration change	
	Input variable change	−	+
Assets	Δr +/− 10 BP	–0.2	+0.2
	Δv +/− 1 year	–0.7	+0.6
	No time passing	–4.1	
Liabilities	Δr +/− 10 BP	–0.7	+0.8
	Δv +/− 1 year	–0.2	+0.2
	No time passing	-2.6	

The table shows the sensitivity of the aggregated duration estimates in Equation (9) to input variations. Aggregation is carried out for 83 German life insurers. Input variables variated are Δr and Δv, both for the asset and the liability duration. Column (1) displays the change of the aggregate duration estimate given a decrease of Δr by 0.1 percentage points (because Δr is negative, it is in absolute terms an increase) and an increase of Δv by 1 year. Column (2) displays the change of the aggregate duration estimate given an increase of Δr by 0.1 percentage points and a decrease of Δv by 1 year. Further, the table displays how the aggregated duration estimate would change if one does not account for the time passing effect.

4.2 Influence of different insurer attributes

To examine the attributes of life insurers with a wide duration gap, I estimate a cross-sectional regression of the following form:

$$Durationgap_i = \alpha + \beta X_i + \epsilon_i \tag{11}$$

where the dependent variable is the historical duration gap of insurers i. Independent variable X_i is a vector of insurer characteristics. To address a small number of extreme values in the dependent variable I use two different approaches. First, I estimate a regression that includes insurers with a duration gap that exceeds the average plus/minus 2.5 times the standard deviation. That way, three observations are excluded. Second, I estimate a robust-to-outliers regression, a method which minimizes the effect of outliers through the use of weights. I use different company attributes as explanatory variables. The first one is size, measured by the natural logarithm of the book value of the premium reserve. A dummy variable is used to control for insurers in run-off. These are insurers that stopped selling new policies (nine insurers in the sample). I also control for growth perspectives, measured by the planned annual premium growth during the period 2015-2018 (median 0.2%). Further dummy variables are used to control for the following aspects: whether the life insurer is the subsidiary of an exchange-listed group (22 insurers); whether the insurer has the legal status of a mutual insurance company (17 insurers); whether the insurer is publicly owned (8 insurers); and whether an insurer used interest rate derivatives as a hedging instrument during the years 2010-2013 (37 insurers). The derivatives data are taken from regulatory reporting. My hypothesis is that the duration gap differs significantly between insurers with different attributes.

Table 2 shows the results. Overall, the regression results indicate two facts. First, there is a strong common component as most insurers have a wide duration gap. One noteworthy aspect is the high coefficient for the constant, which indicates that irrespective of observable insurer attributes, duration gaps tend to be substantially positive. Second, insurers with lower growth, those that are in run-off and those that are small tend to have wider duration gaps. Interpreting these factors independently is, however, difficult because of collinearity.

In principle, the data used in this paper are collected yearly. The 2014 edition used here is the first one that includes data on hidden losses on the liability side, which became observable following a major reform of insurance law in Germany. So far, one more recent version has been available which includes this information, the 2015 edition. Using these new data for comparison, estimates are quite similar to the previous estimates. With the 2015 edition data I obtain an aggregate duration gap of 5.4, which is slightly higher

Table 2: Cross-sectional robust regression: Significance of life insurer attributes

	Column (1) OLS regression		Column (2) Robust regression	
Independent variable:	Coeff.	SE	Coeff.	SE
Planned premium growth	-14.914*	(8.168)	-18.972**	(8.106)
Run-off	-3.111**	(1.316)	-3.483***	(1.205)
Size	-0.462**	(0.209)	-0.523**	(0.217)
Subsidiary of a group	-0.563	(0.809)	-0.620	(0.862)
Mutual insurance company	0.708	(0.847)	0.181	(0.901)
Public ownership	0.407	(1.135)	0.402	(1.210)
Interest rate derivatives	-0.257	(0.730)	-0.366	(0.779)
Constant	13.500***	(2.970)	14.567***	(3.063)
N	80		83	
Adj. R-Squared	0.113			

The table shows results from cross-sectional regression (11). The cross-section includes characteristics of German life insurance entities in the year 2014. The dependent variable is the historical modified duration gap estimated in Equation (10). The regressions include the continuous independent variables: projected premium growth in the years 2015-2018 and size, measured as the natural logarithm of the book value of the premium reserve. Further, it includes, as independent variables, the following dummies: being in run-off, subsidiary of a group, mutual insurance company, public ownership, and use of derivatives as a hedging instrument in the years 2010-2013. Column (1) displays results of an OLS regression with a sample that excludes three observations with a dependent variable that exceeds 2.5 times the average plus/minus the standard deviation. Column (2) displays results of a robust regression for the full sample. Standard errors in brackets. *, ** and *** show a significance level of 0.1, 0.05 and 0.01 respectively.

than the 2014 edition estimate of 4.9. This is the result of an investment duration of 9.5 (instead of 9.9) and a liability duration of 14.9 (instead of 14.7). The median duration gap is 6.6 (instead of 6.1), and the standard deviation is 3.8 (instead of 3.9).

Using the two observation years, I estimate in analogy to Equation (11) the following panel regression

$$Durationgap_{i,t} = \alpha + \beta X_{i,t} + \epsilon_{i,t} \tag{12}$$

with the same independent variables as in Table 2, but with time dimension t. The between standard deviation of the duration gap is 3.8, while the within standard deviation is only 1.0. There are two covariates with variation over time – planned premium growth and size – though both have only little within variation. An estimate including fixed-effects yields coefficients of both covariates with the same algebraic sign as in Table 2, but only the estimate of size is weakly significant. An estimate with random-effects yields a significant negative effect of size and being in run-off, which is the same result as obtained before. However, the effect of planned premium growth is not significant in this setup.

Table 3: Cross-sectional regression: Association between investment and liability duration

Independent variable	Column (1) Robust regression Coeff (SE)	Column (2) Robust regression Coeff (SE)	Column (3) Robust regression Coeff. (SE)
Liability duration	.086** (.036)	.591*** (.107)	.135** (.050)
Sample:	All	Gap≤Median	Gap>Median
N	83	42	41

The table shows results from cross-sectional regression (13). The dependent variable is the historical investment duration. The independent variable is the historical liability duration, both estimated in Equation (9). Column (1) displays results of a robust regression for the full sample. Column (2) displays results of a robust regression for the sample of insurers whose historical duration gap is narrower than its median. Column (3) displays results of a robust regression for the sample of insurers whose historical duration gap, the difference between the historical liability duration and historical investment duration, is wider than its median. Standard errors are in brackets. *, ** and *** show a significance level of 0.1, 0.05 and 0.01 respectively.

4.3 Liability duration and asset-liability management

Asset-liability management implies that insurers with a higher liability duration tend to have a higher asset duration. The idea is that the investment process is liability-driven. An insurer should adjust the duration of its investment portfolio as the duration of its liabilities changes. This implies that, in theory, liability duration causes asset duration. I empirically investigate the asset-liability correlation through a robust-to-outliers regression of investment duration on liability duration.

$$\left(D_{r_0,v_0}^{Assets}\right)_i = \alpha + \beta \left(D_{r_0,v_0}^{Liabilities}\right)_i + \epsilon_i \tag{13}$$

Table 3 displays the results. If insurers seek to exactly match the durations of asset and liabilities, one would expect a coefficient of nearly one. In case asset-liability management takes place, but matching is only done partly, one would expect a coefficient substantially larger than zero but below one. The relationship between asset and liability duration displayed in column (1) is weak but significantly different from zero. However, this result is obtained because the simple regression is not good enough at capturing the relationship. I observe that insurers with a narrow duration gap closely match durations, while insurers with a wide duration gap only match to small extent. In separate regressions for insurers with a narrow gap (column 2) and those with a wide gap (column 3), both separated by the median, the relationship between investment and liability duration is strong and highly significant. The coefficient is much stronger in the sample with a narrow gap. The result suggests that there appear to be two distinct groups of insurers: those with a strong asset-liability match and a narrow duration gap, and those with a less strong asset-liability match and a wider duration gap.

4.4 Duration gap and Solvency II capital ratio

This subsection examines whether there is any link between my estimate of insurers' duration gap and their Solvency II ratios. Because capital ratios in the Solvency II framework are strongly influenced by the interest rate risk module, it is natural that ceteris paribus insurers with a wide duration gap in the past might have higher capital requirements. To aid comparability, I use the reported ratios without the use of transitional measures. The data set is the comprehensive Solvency II survey conducted in 2015 by BaFin. Data are available for 82 insurers. They include preliminary data on solvency ratios without the use of transitional measures, which give insurers an option of a phase-in period of 16 years to switch from Solvency I valuation to Solvency II valuation. This makes it easier to compare Solvency II numbers between insurers. Using robust-to-outliers regression, I estimate the effect of the duration gap on the Solvency II ratio.

$$SII\ Ratio_i = \alpha + \beta Durationgap_i + \epsilon_i \tag{14}$$

Insurers with a narrow historical duration gap tend to have a higher Solvency II ratio. The effect is significant (coefficient -6.3, standard error -2.9). This result indicates that an increase in the historical duration gap by 1 decreases the ratio by 6 percentage points. As an additional check, I transform the solvency ratio into an index from 1 to 82, where 1 is attributed to the insurer with the lowest ratio and 82 to the one with the highest ratio. Again, I find that the effect is significant (coefficient -1.4, standard error 0.8), albeit only at a 10% significance level. One should be careful when interpreting these numbers, because Solvency II ratios are difficult to compare between insurers, volatile in the first years before and after the launch, and it is far from clear what the underlying reason for the correlation might be.

5 Conclusions and discussion

The effect of low interest rates on life insurers has been analyzed in recent research papers, financial stability reviews and analyst reports. It has also been the subject of public debate for quite some time. A topic that has received less attention, however, is the measurement of interest rate risk and the distribution throughout the industry. This paper uses accounting data to derive a new measure of interest rate risk. An estimate for German life insurers illustrates substantial common interest rate risk, albeit with a wide dispersion. This is important for assessing the contribution of the insurance sector to risks to financial stability. A common risk exposure of many insurers entails risks, in particular if it gives rise to aligned investment decisions. This could potentially affect the emergence of exaggerations in capital markets. The wide dispersion implies that insurers are affected differently by the low-interest-rate environment and could, therefore, behave quite differently in times of stress. Future research could take a deeper look at the connection between the distribution of risk exposure within the industry and the degree of alignment in behavior.

It is natural to ask why German life insurers have wide duration gaps. Or to be more precise, given the long duration on the liability side, why do insurers not invest enough in long-dated assets? In the following I discuss a few plausible explanations. First, what is known as the effective duration of insurance liabilities – that is, the duration which takes into account the potential variability of future cash flows – is lower than the modified duration (Briys and De Varenne, 1997, EIOPA, 2016). The main reasons for this are future discretionary benefits, which can be reduced when interest rates fall, and the policyholder option to surrender contracts.[5] As a further point, the lack of transparency and of short-term incentives should be borne in mind. This includes the neglect of the Solvency I regulatory framework to capture interest rate risk.[6] In addition, financial statements often follow local GAAP reporting standards and historical cost accounting methods, and therefore do not disclose the interest rate sensitivity of assets and liabilities. According to Moody's (2015), duration gaps are narrower in countries in which they are penalized through specific reserve requirements or through market-consistent valuation on the balance sheet. Koijen and Yogo (2014) and Ellul et al. (2015) highlight that non-economic pricing of life insurance liabilities in external accounting and/or capital regulation can distort managerial decisions and mask differences in interest rate sensitivity between investments and liabilities.

Against this background, a major argument put forward is a shortage of long-term bonds (e.g. Frey, 2012). In addition, a dearth of long-term bonds puts pressure on yields at the long end of the maturity spectrum (Greenwood and Vayanos, 2010). Furthermore, it is possible that insurers pursue a wide duration gap as part of their investment strategy. Timmer (2016) suggests that insurers invest countercyclically; they tend to sell debt securities when prices have increased, and tend to buy when prices have decreased. This implies that insurers prefer to lower their asset duration in an environment of falling interest rates.

[5] In Germany even at a fixed surrender value. Duration matching increases liquidity risk given rate-insensitive surrender values, since policy lapses become more attractive for all policyholders when interest rates rise. Feodoria and Förstemann (2015) model the risk of a surge in lapses following a sharp rise in interest rates.

[6] Solvency I was the regulatory regime in Germany until the end of 2015. Under this regime, capital requirements were independent of the asset portfolio and not sensitive to decreasing interest rates. Fleuriet and Lubochinsky (2005) demonstrate the effect of regulation using the example of a reform in Denmark: following a stipulated change in the discount rates used for premium reserves, Danish life insurers substantially increased the duration of their investments.

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